SWORN TRANSLATION

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Date: September 6, 2007

Declarant: Jun Inoh

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[Identification of Document]	Petition for Patent Application
[Reference Number]	P236068
[Date of Submission]	December 24, 2002
[Addressee]	Commissioner, Patent Office: Shinichiro OTA
[International Patent Classification]	G09F 9/37
[Title of Invention]	IMAGE DISPLAY DEVICE
[Number of Claims]	4
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[Deposit Account Number]	074997
[Amount of Payment]	¥21,000

[List of Attached Items]	
[Identification of Item]	Specification: 1
[Identification of Item]	Drawing: 1
[Identification of Item]	Abstract: 1
[General Authorization Number]	9712186
[Request for Proof]	Yes

[Identification of Document] SPECIFICATION

[Title of the Invention] IMAGE DISPLAY DEVICE

[Claims]

[Claim 1] An image display device which comprises an image display panel, in which two or more groups of particles having different colors and different charge characteristics are sealed in a plurality of cells formed by partition walls between two substrates, at least one of two substrates being transparent, and, in which the particles, to which an electrostatic field is applied from electrodes provided to both of the substrates, are made to move so as to display an image,

characterized in that a coating area of the electrode provided on two substrates respectively is patternized with respect to a projected area of respective cells.

[Claim 2] The image display device according to claim 1, wherein at least one of the electrodes provided on the two substrates respectively has a coating area in respective cells of 5-99 % with respect to a projected area of respective cells.

[Claim 3] The image display device according to claim 1, wherein at least one of the electrodes provided on the two substrates respectively has a coating area in respective cells of 30 - 90 % with respect to a projected area of respective cells.

[Claim 4] The image display device according to claim 2 or 3, wherein a contact dimension between at least one of the electrodes provided on the two substrates respectively and the partition wall is less than 50 % of an inner peripheral dimension of respective cells.

[Detailed Explanation of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to an image display device comprising an image display panel enables to repeatedly display or erase images accompanied by flight and movement of particles utilizing Coulomb's force and so on and particularly relates to an image display device in which image having an excellent uniformity can be displayed.

[Background Art]

[0002]

Heretofore, as an image display device substitutable for liquid crystal display (LCD), image display devices with the use of technology such as an electro-phoresis

method, an electro-chromic method, a thermal method, dichroic-particles-rotary method are proposed.

[0003]

As for these image display devices, since it is conceivable as a technique usable for inexpensive visual display device of the next generation from a merit having wide field of vision close to normal printed matter, having smaller consumption and having a memory function in comparison with LCD, spreading out to a display for portable device, and an electronic paper is expected. Recently, electrophoresis method (for example, see non-patent literature 1) is proposed and expected that microencapsulate dispersion liquid made up with dispersion particles and coloration solution and dispose the liquid between faced substrates.

[0004]

However, in the electrophoresis method, there is a problem that a response rate is slow by the reason of viscosity resistance of the solution because the particles migrate among the electrophoresis solution. Further, there is a problem of lacking imaging repetition stability, because particles with high specific gravity such as titanium oxide is scattered within solution of low specific gravity, it is easy to subside, difficult to maintain a stability of dispersion state. Even in the case of microencapsulating, cell size is diminished to a microcapsule level in order to only make it hard to appear the defects described above seemingly, however, an essential problem was not overcome at all.

[0005]

Besides the electrophoresis method using behavior in the solution, recently, a method wherein electro-conductive particles and a charge transport layer are installed in a part of the substrate without using solution is proposed. However, the structure becomes complicated because the charge transport layer and further a charge generation layer are to be arranged. In addition, it is difficult to constantly inject charges into the electro-conductive particles, and thus there is a drawback on the lack of stability.

[0006]

[Non-Patent Literature 1]

Chou Kokurai et al (three besides) "New Toner Display Devise (I)", The Imaging Society of Japan annual conference (83 times in total) "Japan Hardcopy' 99" (July 21, 1999) Transaction Pages 249-252

[0007]

[Problems to be Solved by the Invention]

In order to solve the problems mentioned above, it is known an image display device which comprises an image display panel, in which two or more groups of particles having different colors and different charge characteristics are sealed in a plurality of cells formed by partition walls between two substrates, at least one of two substrates being transparent, and, in which the particles, to which an electrostatic field is applied from electrodes provided to both of the substrates, are made to fly and move so as to display an image by utilizing Coulomb's force.

[0008]

In such an image display device mentioned above, for example, a plurality of cells are formed between two substrates in such a manner that: a transparent conductive material such as ITO and so on formed on a surface of a glass substrate is etched so as to form a electrode such as a line shape and so on by patterning; and partition walls are formed thereon by utilizing a photo-resist. In this case, since a coating area of the conductive material is made to be 100 % with respect to a projected area of respective cells, the particles are unevenly distributed to a portion of the partition walls formed around respective cells after driving a display cell. As a result, the particles not only come short at a center portion of respective cells but also produce three groups of agglutination members such as "positive charge - positive charge", "positive charge - negative charge" and "negative charge - negative charge" when the particles are gathered at the partition walls due to van der Waals force, electrostatic force and so on. Thereby, there can not be driven a display element, and at the same time, there is a problem such that: "particle drop (phenomenon wherein a display due to a part of the particles in the display element is missed)" is generated at the center portion of respective cells; and thus an appearance becomes worse.

[0009]

The present invention is achieved by paying attention to the problems mentioned above and has for its object to provide an image display device which can display image having an excellent uniformity due to a prevention of uneven particle distribution to the partition walls and a prevention of particle drop at the center portion of respective cells, by using a pattern electrode which defines a coating area of the electrode with respect to a projected area of respective cells.

[0010]

[Means for Solving Problems]

In order to achieve the object mentioned above, an image display device of the invention which comprises an image display panel, in which two or more groups of particles having different colors and different charge characteristics are sealed in a plurality of cells formed by partition walls between two substrates, at least one of two substrates being transparent, and, in which the particles, to which an electrostatic field is applied from electrodes provided to both of the substrates, are made to move so as to display an image, is characterized in that a coating area of the electrode provided on two substrates respectively is patternized with respect to a projected area of respective cells.

[0011]

In the image display device according to the invention having the construction mentioned above, it is possible to provide the image display device having rapid response rate due to a dry type display, simple construction, inexpensive cost and excellent stability, by constructing a new image display device in which image display elements enabling to move the particles, to which electrostatic field is directly applied, are arranged in a matrix manner. Further, since a coating area of the electrode provided on two substrates respectively is patternized with respect to a projected area of respective cells, the uneven particle distribution to the partition walls and the particle drop at the center portion of respective cells can be prevented, and thus it is possible to provide the image display device which can display image having an excellent uniformity.

[0012]

In the image display device according to the invention, in order to prevent the uneven particle distribution to the partition walls and the particle drop at the center portion of respective cells, it is preferred that at least one of the electrodes provided on the two substrates respectively has a coating area in respective cells of 5-99 % with respect to a projected area of respective cells, or, that at least one of the electrodes provided on the two substrates respectively has a coating area in respective cells of 5-99 % with respect to a projected area of respective cells.

[0013]

Moreover, in the image display device according to the invention, in order to further prevent the uneven particle distribution to the partition walls and the particle drop at the center portion of respective cells, it is preferred that a contact dimension between at

least one of the electrodes provided on the two substrates respectively and the partition wall is less than 50 % of an inner peripheral dimension of respective cells.

[0014]

[Embodiments of the Invention]

Hereinafter, the embodiments according to the invention will be explained in detail with reference to the drawings. Fig. 1 is a schematic view illustrating one embodiment of the image display element of the image display panel constructing the image display device according to the invention, and display driving theory. In the embodiments shown in Figs. 1(a) to 1(c), numeral 1 is a transparent substrate, numeral 2 is an opposed substrate, numeral 3 is a display electrode (transparent electrode), numeral 4 is an opposed electrode, numeral 5 is a negatively chargeable particle, numeral 6 is a positively chargeable particle and numeral 7 is a partition wall.

[0015]

Fig. 1(a) shows a state such that the negatively chargeable particles 5 and the positively chargeable particles 6 are arranged between opposed substrates (transparent substrate 1 and opposed substrate 2). Under such a state, when a voltage is applied in such a manner that a side of the display electrode 3 becomes low potential and a side of the opposed electrode 4 becomes high potential, as shown in Fig. 1(b), the positively chargeable particles 6 fly and move to the side of the display electrode 3 and the negatively chargeable particles 5 fly and move to the side of the opposed electrode 4 by means of Coulomb's force. In this case, a display face viewed from a side of the transparent substrate 1 looks like a color of the positively chargeable particles 6. Next, when a voltage is applied in such a manner that the side of the display electrode 3 becomes high potential and the side of the opposed electrode 4 becomes low potential by reversing potentials, as shown in Fig. 1(c), the negatively chargeable particles 5 fly and move to the side of the display electrode 3 and the positively chargeable particles 6 fly and move to the side of the opposed electrode 4 by means of Coulomb's force. In this case, the display face viewed from the side of the transparent substrate 1 looks like a color of the negatively chargeable particles 5.

[0016]

The display states shown in Figs. 1(b) and 1(c) can be repeatedly display only by reversing the potentials of a power source, and thus it is possible to change colors on the display face reversibly by reversing the potentials of the power source as

mentioned above. The colors of the particles can be arbitrarily selected. For example, when the negatively chargeable particles 5 are white color and the positively chargeable particles 6 are black color, or, when the negatively chargeable particles 5 are black color and the positively chargeable particles 6 are white color, display is a reversible image display between white color and black color. In this method, when the display is once performed, since the particles are at a state of being adhered to the electrode by means of an imaging force, a display image can be maintained for a long time after a voltage apply is stopped, thereby showing an excellent memory property.

[0017]

In the invention, since the chargeable particles fly in the gas, the response speed of the image display is extremely fast and the response speed of shorter than 1 msec may be possible. Moreover, it is not necessary to use an orientation film, a polarizing plate and the like as the liquid crystal display, and thus it is possible to make the structure simple and to realize the image display device having a large display area at a lower cost. In addition, it is stable with respect to a temperature variation and can be used from a low temperature to a high temperature. Further, it is not affected by an angle of visual field and has a high reflection coefficient and reflecting. Therefore, it is easily viewable at well-lighting areas and has low electric power consumption. Furthermore, it has a memory property and thus it is not necessary to use an electric power when the image is to be maintained.

[0018]

The image display device according to the invention comprises the image display panel in which the image display element mentioned above is arranged in a matrix manner. Figs. 2(a) and 2(b) show such one embodiment respectively. In this embodiment, 3×3 matrix is shown for convenience of explanation. When the number of the electrodes is n, it is possible to construct an arbitrary n×n matrix.

[0019]

In the embodiment shown in Figs. 2a and 2b, display electrodes 3-1 to 3-3 arranged substantially in parallel with each other and opposed electrodes 4-1 to 4-3 arranged substantially in parallel with each other are provided respectively on the transparent substrate 1 and the opposed substrate 2 in such a manner that they are intersected with each other. Serial switches SW3-1-1, SW3-2-1 and SW3-3-1 are respectively connected to the display electrodes 3-1 to 3-3. In the same way, serial

switches SW4-1-1, SW4-2-1 and SW4-3-1 are respectively connected to the opposed electrodes 4-1 to 4-3. Further, serial switch SW3-1-2 is connected to SW3-1-1, SW3-2-1 and SW3-3-1 in common, and serial switch SW4-1-2 is connected to SW4-1-1, SW4-2-1 and SW4-3-1 in common.

[0020]

The switches SW3-n-1 (n=1-3) and the switches SW4-n-1 (n=1-3) serve to switch the connection toward a ground level and the connection toward the next SW3-1-2, respectively. The switches SW3-1-2 and the switches SW4-1-2 serve to switch the connection toward a high voltage generating circuit 8 and the connection toward a low voltage generating circuit 9 respectively. The all the serial switches SW constitute a matrix drive circuit 10. In this embodiment, the 3×3 image display elements are constructed by isolating them by means of the partitions 7.

[0021]

In driving control against the matrix electrode constructed by the display electrodes 3-1 to 3-3 and the opposed electrodes 4-1 to 4-3 mentioned above, the operation is performed in such a manner that, in accordance with the image to be displayed, open/close operations of respective switches SW are controlled by means of a sequencer not shown and the 3×3 image display elements are displayed in sequence. This operation is the same as that of the known image display operation basically.

[0022]

With respect to respective electrodes constituting the matrix electrode, in the case of the display electrode provided on the transparent substrate, it is formed of electroconductive materials, which are transparent and have pattern formation capability. As such electroconductive materials, metals such as aluminum, silver, nickel, copper and gold, or transparent electroconductive metal oxides such as ITO, electroconductive tin oxide and electroconductive zinc oxide formed in the shape of thin film by sputtering method, vacuum vapor deposition method, CVD method, and coating method, or materials obtained by applying the mixed solution of an electroconductive agent with a solvent or a synthetic resin binder are used.

[0023]

As typical examples of the electroconductive materials, there are used cationic polyelectrolyte such as benzyltrimethylammonium chloride, tetrabutylammonium perchlorate and so on, anionic polyelectrolyte such as

polystyrenesulfonate, polyacrylate, and so on, or electroconductive fine powders of zinc oxide, tin oxide, indium oxide or the like. Additionally, the thickness of the electrode may be suitable unless the electroconductivity is absent or any hindrance exists in optical transparency, and it is preferable to be 3 to 1000 nm, more preferable to be 5 to 400 nm. The transparent electrode materials can be employed on the opposed substrate in the same way as the foregoing display electrode, and non-transparent electrode materials such as aluminum, silver, nickel, copper and gold can be also employed.

[0024]

It is preferred that an insulation coating layer is formed on the each electrode so as not to reduce charges of the charged particles. As such insulation coating layer, if use is made of a positively chargeable resin with respect to the negatively chargeable particles and a negatively chargeable resin with respect to the positively chargeable particles, the charges of the particles are to be difficult to reduce and it is particularly preferable.

[0025]

Hereinafter, the substrate used in the image display device according to the invention will be explained. With respect to the substrate, at least one of the substrates is the transparent substrate through which a color of the particles can be observed from outside of the device, and it is preferred to use a material having a high transmission factor of visible light and an excellent heat resistance. Whether flexibility is necessary or not is suitably selected in accordance with its use. For example, it is preferred to use a material having flexibility for the use of electronic paper and so on, and it is preferred to use a material having no flexibility for the use of a display of portable device such as mobile phone, PDA, laptop computer and so on.

[0026]

Examples of the substrate material include polymer sheets such as polyethylene terephthalate, polyether sulfone, polyethylene, polycarbonate, polyimide or acryl and inorganic sheets such as glass, quartz or so. The opposed substrate may be transparent or may be opaque. The thickness of the substrate is preferably 2 to 5000 μm, more preferably 5 to 1000 μm. When the thickness is too thin, it becomes difficult to maintain strength and distance uniformity between the substrates, and when the thickness is too thick, vividness and contrast as a display capability degrade, and in particular, flexibility in the case of using for an electronic paper deteriorates.

[0027]

Moreover, as shown in Fig. 2(a), it is preferred to arrange the partition wall 7 around respective display elements. The partition may be also provided in two directions parallel to each other. In this manner, it is possible to prevent an unnecessary movement of the particles in a direction parallel to the substrate, to help a repeatedly endurance property and a memory maintaining property and to improve a strength of the image display panel by making a distance between the substrates even and strong.
The formation method of the partition wall is not particularly restricted, however, a screen printing method wherein pastes are overlapped by coating repeatedly on a predetermined position by screen plate; a sandblast method wherein partition materials are painted with a desired thickness entirely over the substrate and then after coating resist pattern on the partition materials which is wanted to be left as a partition, jetting abrasive to cut and remove partition materials aside from the partition part; lift-off method (additive method) wherein a resist pattern is formed on the substrate using photosensitive polymer, and then after burying paste into a resist recess, removing the resist; photosensitive paste method wherein the photosensitive resin composition containing the partition materials is applied over the substrate and then obtaining a desired pattern by exposure & developing; and mold formation method wherein paste containing the partition materials is applied over the substrate and then forming a partition by compression bonding & pressure forming the dies having rugged structure; and so on are adopted. Further, modifying the mold formation method, relief embossing method wherein a relief pattern provided by a photosensitive polymer composition is used as a mold is also adopted.
[0028]

Hereinafter, the particles used in the image display device according to the invention will be explained. In the present invention, as the particles for display, although any of colored particles negatively or positively chargeable having capability of flying and moving by Coulomb's force are employable, spherical particles with light specific gravity are particularly preferable. The average particle diameter of the particles is preferable to be 0.1 to 50 μm, particularly to be 1 to 30 μm. When the particle diameter is less than this range, charge density of the particles will be so large that an imaging force to an electrode and a substrate becomes too strong; resulting in poor following ability at the inversion of its electric field, although the memory characteristic is favorable. On the contrary, when

the particle diameter exceeds the range, the following ability is favorable, but the memory characteristic will degrade.

[0029]

Although the method for charging the particles negatively or positively is not particularly limited, a corona discharge method, an electrode injection-charge method, a friction charge method and so on are employable. It is preferred that the particle measured by a blow-off method by using carriers has a surface charge density not less than 5 $\mu m/m^2$ and not greater than 150 $\mu m/m^2$ in absolute value. When the absolute value of the surface charge density of the particles is smaller than this range, the response speed in response to a change of the electrostatic field becomes slower and the memory characteristics become lower. When the absolute value of the surface charge density of the particles is larger than this range, an imaging force to the substrate and electrode becomes too stronger. Therefore, the following ability at the inversion of its electric field becomes poor, but the memory characteristic is favorable.

A charge amount measurement and a particle gravity measurement, which are necessary to calculate the surface charge density used in the invention, can be performed as mentioned below. That is, according to a blow-off method, the particles and carrier particles are sufficiently contacted and a saturated charge amount thereof is measured, so that a charge amount per a unit weight of the particles can be measured. Then, a particle diameter and a specific gravity of the particles are separately measured, and the surface charge density of the particles is calculated by using them.

<Blow-off measuring theory and method>

In the blow-off method, a mixture of the powders and the carriers are placed into a cylindrical container with nets at both ends, and high-pressure gas is blown from the one end to separate the powders and the carriers, and then only the powders are blown off (exsufflation) from the mesh of the net. In this occasion, charge amount of reverse blown polarity remains on the carriers with the same charge amount of the powders carried away out of the container. Then, all of electric flux by this electric charge are collected to Faraday cage, and are charged across a capacitor with this amount. Accordingly, the charge amount Q of the powders is determined as Q=CV (C: capacity, V: voltage across both ends of the capacitor) by measuring potential of both ends of the capacitor.

As a blow-off powder charge amount measuring instrument, TB-200 produced by Toshiba Chemical Co., Ltd. was used. In the invention, two kinds of particles negatively or positively chargeable were used as carriers, and the charge density per unit surface area (unit: $\mu C/m^2$) was calculated in each cases. That is, F963-2535 available from Powder TEC Co., Ltd. was employed as the positively chargeable carrier (carrier which charges the opponent positively and is easy to charge itself negatively), and F921-2535 available from Powder TEC Co., Ltd. was employed as the negatively chargeable carrier (carrier which charges the opponent negatively and is easy to charge itself positively).

<Specific gravity of the particles measuring method>

A specific gravity of the particles was measured by a specific gravity meter, a multi-volume density meter H1305 produced by Shimadzu Corporation.

[0030]

Because it is necessary for the particles to hold the charged electric charge, insulating particles with the volume specific resistance of 1×10^{10} Ω·cm or greater are preferable, and in particular, insulating particles with the volume specific resistance of 1×10^{12} Ω·cm or greater are more preferable. Further, the particles with slow charge attenuation property evaluated by the measuring method below are more preferable.

[0031]

That is, the particles are separately made into a film having a thickness of 5-100 μm by means of a press method, a heating/melting method, a casting method and so on. The voltage of 8 kV is applied to a Corona generator disposed with a distance of 1 mm to the film surface so as to generate Corona discharge, which charges the film surface. Then, the change of the surface potential is measured to determine. In this occasion, it is essential that it is preferable to select the material whose maximum surface potential will be more than 300 V after 0.3 seconds, more preferable to select the material whose maximum surface potential will be more than 400 V the material for composing the particles.

[0032]

Additionally, the foregoing surface potential is measured, for example, by means of an instrument (CRT2000 produced by QEA Inc.) as shown in Fig. 3. In case of this instrument, both end portions of a roll shaft disposed the foregoing film on the surface thereof are held with chuck 21, facedly deploying the measurement unit, which is

provided compact scorotron discharger 22 along with surface potential meter 23 by predetermined interval, with a distance of 1 mm from the surface of the film, and by moving the measurement unit from one end portion of the film to the other end portion with an uniform speed, with the state that the foregoing film remains stopping and while giving surface charge, a method of measuring its surface potential is preferably adopted. Moreover, measurement environment should be settled at the temperature of 25 ± 3°C and the humidity of 55 ± 5% RH.

[0033]

If the particles satisfy electrostatic property and so on, the particles may be formed by any materials. For example, it is formed by resin, charge control agent, coloring agent, inorganic additive and so on, or, by coloring agent and so on only.

[0034]

Typical examples of the resin include urethane resin, urea resin, acrylic resin, polyester resin, acryl urethane resin, acryl urethane silicone resin, acryl urethane fluorocarbon resin, acryl fluorocarbon resin, silicone resin, acryl silicone resin, epoxy resin, polystyrene resin, styrene acrylic resin, polyolefin resin, butyral resin, vinylidene chloride resin, melamine resin, phenolic resin, fluorocarbon resin, polycarbonate resin, polysulfon resin, polyether resin, and polyamide resin. Two kinds or more of these may be mixed and used. For the purpose of controlling the attaching force with the substrate, acryl urethane resin, acryl silicone resin, acryl fluorocarbon resin, acryl urethane silicone resin, acryl urethane fluorocarbon resin, fluorocarbon resin, silicone resin are particularly preferable.

[0035]

Examples of the electric charge control agent include, but not particularly specified to, negative charge control agent such as salicylic acid metal complex, metal containing azo dye, oil-soluble dye of metal-containing (containing a metal ion or a metal atom), the fourth grade ammonium salt-based compound, calixarene compound, boron-containing compound (benzyl acid boron complex), and nitroimidazole derivative. Examples of the positive charge control agent include nigrosine dye, triphenylmethane compound, the fourth grade ammonium salt compound, polyamine resin, imidazole derivatives, etc. Additionally, metal oxides such as ultra-fine particles of silica, ultra-fine particles of titanium oxide, ultra-fine particles of alumina, and so on; nitrogen-containing circular compound such as pyridine, and so on, and these derivates or salts; and resins

containing various organic pigments, fluorine, chlorine, nitrogen, etc. can be employed as the electric charge control agent.

[0036]

As for a coloring agent, various kinds and colors of organic or inorganic pigments or dye as will be described below are employable.

[0037]

Examples of black pigments include carbon black, copper oxide, manganese dioxide, aniline black, and activate carbon. Examples of yellow pigments include chrome yellow, zinc chromate, cadmium yellow, yellow iron oxide, mineral first yellow, nickel titanium yellow, navel yellow, naphthol yellow S, hanzayellow G, hanzayellow 10G, benzidine yellow G, benzidine yellow GR, quinoline yellow lake, permanent yellow NCG, and tartrazinelake. Examples of orange pigments include red chrome yellow, molybdenum orange, permanent orange GTR, pyrazolone orange, Balkan orange, Indanthrene brilliant orange RK, benzidine orange G, and Indanthrene brilliant orange GK. Examples of red pigments include red oxide, cadmium red, diachylon, mercury sulfide, cadmium, permanent red 4R, lithol red, pyrazolone red, watching red, calcium salt, lake red D, brilliant carmine 6B, eosin lake, rhodamine lake B, alizarin lake, and brilliant carmine 3B.

[0038]

Examples of purple pigments include manganese purple, first violet B, and methyl violet lake. Examples of blue pigments include Berlin blue, cobalt blue, alkali blue lake, Victoria blue lake, phthalocyanine blue, metal-free phthalocyanine blue, partially chlorinated phthalocyanine blue, first sky blue, and Indanthrene blue BC. Examples of green pigments include chrome green, chromium oxide, pigment green B, Malachite green lake, and final yellow green G. Further, examples of white pigments include zinc white, titanium oxide, antimony white, and zinc sulphide.

[0039]

Examples of extenders include barite powder, barium carbonate, clay, silica, white carbon, talc, and alumina white. Furthermore, there are Nigrosine, Methylene Blue, rose bengal, quinoline yellow, and ultramarine blue as various dyes such as basic dye, acidic dye, dispersion dye, direct dye, etc. These coloring agents may be used alone or in combination of two or more kinds thereof. Particularly, carbon black is preferable as the black coloring agent, and titanium oxide is preferable as the white coloring agent.

[0040]

Although the manufacturing method of the particles is not specifically restricted, grinding method or polymerization method for producing toner of electrophotography is, for example, employable. Further the method of coating resin or charge control agent and so on over the surface of powders such as inorganic or organic pigments is also employable.

[0041]

The distance between the transparent substrate and the opposed substrate is suitably adjusted in a manner where the particles can fly and move, and maintain the contrast of image display; however, it is adjusted usually within 10 to 5000 μm, preferably within 30 to 500 μm. Moreover, the particle filling amount (volume occupying rate) of the particles existing in the space between the substrates is preferable to be 5 to 80 vol%, more preferable to be 10 to 70 vol%.

[0042]

In the image display panel used in the image display device according to the invention, plural of the foregoing display elements are used and disposed in a matrix form, and images can be displayed. In the case of monochrome display, one display element makes one pixel. In the case of displaying any color other than monochrome, combination of colors of the particles is conducted. In the case of full color display, three kinds of display elements, i.e., one group of display elements each having color of R (red), G (green) and B (blue) respectively and each having particles of black is made, and plurality of these sets are disposed as a image display panel.

[0043]

The image display device according to the invention is applicable to the image display unit for mobile equipment such as notebook personal computers, PDAs, cellular phones and so on; to the electric paper for electric book, electric newspaper and so on; to the bulletin boards such as signboards, posters, blackboards and so on; to the image display unit for electric calculator, home electric application products, auto supplies and so on.

[0044]

Then, various examples of the pattern electrode in the image display device according to the invention will be explained. In the image display device according to the

invention, a pattern electrode 12 shown in Figs. 4(a), 4(b) and 4(c) (pattern electrodes 12-1 - 12-3) is used.

The pattern electrode 12 (the pattern electrodes 12-1 - 12-3) according to the invention is patternized to have a predetermined pattern with respect to respective cells 11 formed by a frame-like partition wall 7, and is used as the display electrode 3 and the opposed substrate 4.

[0045]

The pattern electrode 12-1 shown in Fig. 4(a) (hereinafter, referred as electrode 1) is constructed only by a linear portion 12-1a in such a manner that line spaces are formed at left and right ends in the cell 11.

The pattern electrode 12-2 shown in Fig. 4(b) (hereinafter, referred as electrode 2) is constructed by a linear portion 12-2a and a square portion 12-2b in such a manner that line spaces are formed at upper, lower, left and right ends in the cell 11.

The pattern electrode 12-2 shown in Fig. 4(c) (hereinafter, referred as electrode 3) is constructed by a linear portion 12-3a and a circular portion 12-3b in such a manner that spaces are formed at upper, lower, left and right peripheral portions in the cell 11.

[0046]

Pattern electrodes 13 (13-1 - 13-3) shown in Figs. 5(a), 5(b) and 5(c) are comparative examples so as to be compared with the above examples of the pattern electrodes in the image display device according to the invention.

The pattern electrode 13-1 shown in Fig. 5(a) (hereinafter, referred as electrode 4) is constructed only by a linear portion 13-1a, which covers overall portion in the cell 11.

The pattern electrode 13-2 shown in Fig. 5(b) (hereinafter, referred as electrode 5) is constructed only by a narrow linear portion 13-2a, which covers only a center portion in upper and lower directions in the cell 11.

The pattern electrode 13-3 shown in Fig. 5(c) (hereinafter, referred as electrode 6) is constructed by a linear portion 13-3a and a hollow portion 13-3b in such a manner that a square space is formed at a center portion in the cell 11.

[0047]

The image display devices including the electrode 1 - electrode 6 were manufactured as follows.

<Manufacture of electrode pattern>

The electrode 1 - electrode 6 were obtained in such a manner that a dry film-resist was adhered to an indium oxide glass having thickness of about 500 Å, and an exposing step, a developing step and an etching step were performed through a positive mask of respective electrode patterns.

<Manufacture of partition wall>

The pattern electrodes (electrode 1 - electrode 6) with the partition wall shown in Figs. 4(a) - 4(c) and Figs. 5(a) - 5(c) were obtained in such a manner that a dry film-resist having a thickness of 50 μm was adhered to respective electrodes manufactured as mentioned above, and an exposing step and a developing step were performed through a negative mask of a partition wall pattern of 50 μm partition wall and 50 μm-square cell.

[0048]

<Manufacture of particles>

Two kinds of the particles (particles A, particles B) were prepared.

The particles A (black color particles) were manufactured by adding CB 4 phr, charge control agent: BontronN07 (Orient Chemical Industries Ltd.) 2 phr into acrylic urethane resin: EAU53B (Asia Industry Co., Ltd.) / IPDI cross-linking agent: Excel-Hardener HX (Asia Industry Co., Ltd.), mixing them, and then grounding and classifying by a jet-mill.

The particles B (white color particles) were manufactured by adding titanium oxide 10 phr, charge control agent: BontronE89 (Orient Chemical Industries Ltd.) 2 phr into acrylic urethane resin: EAU53B (Asia Industry Co., Ltd.) / IPDI cross-linking agent: Excel-Hardener HX (Asia Industry Co., Ltd.), mixing them, and then grounding and classifying by the jet-mill.

After that, the particles A and the particles B were filled to the thus prepared substrate, on which the pattern electrodes with the partition wall were arranged by 12 g/m^2 respectively with respect to the projected area of the cell 11. Then, the same kind of the substrate, on which the pattern electrodes with the partition wall were arranged, was aligned to be the opposed substrate, and connected to the substrate mentioned above by using epoxy adhesive, so that the image display device in which a distance between the opposed substrates was 100 μm.

[0049]

<Estimation of display function>

A voltage of 200 V was applied between the electrodes of the thus manufactured image display device, and performances after inversion at 50 times (initial state) and after inversion at 10000 times (endured state) were measured.

As the estimation method of the display function, a reflectance of white display and a reflectance of black display were measured at a center portion of the cell by means of EYE SCALE 3 (Eye-Systems Incorporated), and then it was assumed as NG that a contrast of the initial state or the endured state was not greater than 3. Here, a contrast ratio was determined as contrast ratio = reflectance density of black display / reflectance density of white display.

[0050]

If summarized the above, specifications of the electrode 1 - electrode 6 were summarized as the following Table 1, and estimations of the electrode 1 - electrode 6 were summarized as the following Table 2.

[0051]

[Table 1]

		Electrode 1	Electrode 2	Electrode 3	Electrode 4	Electrode 5	Electrode 6
Width of partition wall	μm	50	50	50	50	50	50
Height of partition wall	μm	50	50	50	50	50	50
Area of display portion (1)	mm^2	0.25	0.25	0.25	0.25	0.25	0.25
Inner circumference of display portion (2)	μm	2000	2000	2000	2000	2000	2000
Electrode area in display portion (3)	mm^2	0.20	0.20	0.13	0.25	0.01	0.13
Contact portion between electrode and partition wall (4)	μm	800	100	100	2000	20	2000
(3)/(1)	%	80	80	52	100	4	52
(4)/(2)	%	40	5	5	100	1	100

[0052]

[Table 2]

		Example 1	Example 2	Example 3	Comparative Example 1	Comparative Example 2	Comparative Example 3
Electrode category (1)	μm	Electrode 1	Electrode 2	Electrode 3	Electrode 4	Electrode 5	Electrode 6
Electrode category (2)	μm	Electrode 1	Electrode 2	Electrode 3	Electrode 4	Electrode 5	Electrode 6
After inversion at 50 times	reference of white display %	29.8	33.0	28.0	31.9	21.3	29.0
	reference of black display %	4.2	4.4	4.3	4.2	14.2	16.1
	Contrast	7.1	7.5	6.5	7.6	1.5	1.8
After inversion at 10000 times	reference of white display %	28.6	30.8	28.1	14.0	17.3	25.9
	reference of black display %	80	80	52	100	4	52
	Contrast	6.5	6.7	6.1	2.7	1.2	1.6
Estimation		○	○	○	×	×	×

[0053]

From the results shown in Table 1 and Table 2, the electrode 1 - electrode 3 of the examples 1 - 3, in which a coating area of the electrode in respective cells was 80 %, 80 %, 52 % with respect to the projected area of respective cells, and, in which a contact

dimension between the electrode and the partition wall was 40 %, 5 %, 5 %, were estimated as OK. However, the electrode 4 - electrode 6 of the comparative examples 1 - 3, in which a coating area of the electrode in respective cells was 100 %, 4 %, 2 % with respect to the projected area of respective cells, and, in which a contact dimension between the electrode and the partition wall was 100 %, 1 %, 100 %, were estimated as NG. Therefore, there were concluded as follows.

(1) It is preferred that at least one of the electrodes provided to the two substrates respectively has a coating area of the electrode in respective cells such that it is 5-99 % with respect to the projected area of respective cells.

(2) It is further preferred that at least one of the electrodes provided to the two substrates respectively has a coating area of the electrode in respective cells such that it is 30-90 % with respect to the projected area of respective cells.

(3) It is preferred that a contact dimension between at least one of the electrodes provided to the two substrates respectively and the partition wall is less than 50% of an inner peripheral dimension of respective cells.

Therefore, it is possible to obtain the image display panel with display function having an excellent uniformity from the examples 1-3 corresponding to the electrode 1 - electrode 3, which satisfy all the conditions (1) - (3) mentioned above.

[0054]

In the embodiment mentioned above, the electrodes (display electrode and opposed electrode) are arranged to the substrates (transparent substrate and opposed substrate). In this case, a term "arranged to the substrate" means not only the case such that "the electrode is arranged on the substrate" but also the case such that "the electrode is separately arranged on the substrate".

[0055]

[Effect of the Invention]

As mentioned above, in the image display device according to the invention, it is possible to provide the image display device having rapid response rate due to a dry type display, simple construction, inexpensive cost and excellent stability, by constructing a new image display device in which image display elements enabling to move the particles, to which electrostatic field is directly applied, are arranged in a matrix manner. Moreover, since a coating area of the electrode provided on two substrates respectively is patternized with respect to a projected area of respective cells, the uneven particle

distribution to the partition walls and the particle drop at the center portion of respective cells can be prevented, and thus it is possible to provide the image display device which can display image having an excellent uniformity.

[Brief Description of the Drawings]

[FIG. 1] (a) - (c) are schematic views respectively explaining one embodiment of a display element of an image display panel utilized in an image display device according to the invention, and its display driving theory.

[FIG. 2] (a) and (b) are schematic views respectively illustrating the image display panel of the image display device according to the invention.

[FIG. 3] It is a schematic view showing a method for measuring a surface potential of particles utilized in the image display device according to the invention.

[FIG. 4] (a) - (c) are schematic views respectively illustrating a pattern electrode with the partition wall in examples 1-3 according to the invention.

[FIG. 5] (a) - (c) are schematic views respectively illustrating the pattern electrode with the partition wall in comparative examples 1 - 3 according to the invention.

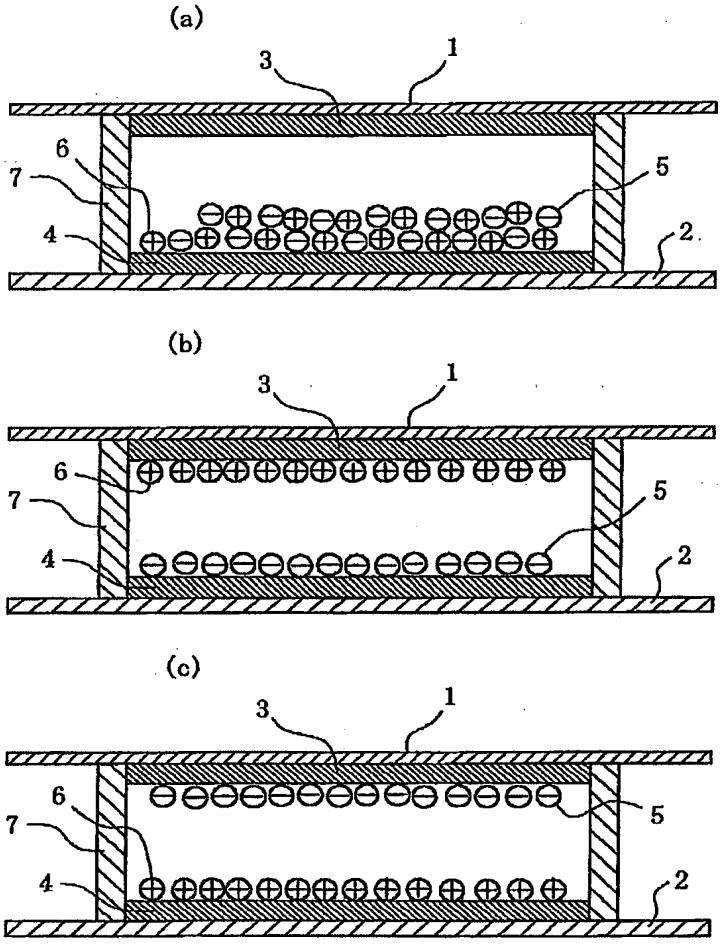
[Description of Reference Symbols]

1	transparent substrate
2	opposed substrate
3	display electrode
4	opposed electrode
5	negatively chargeable particle
6	positively chargeable particle
7	partition wall
8	high voltage generating circuit
9	low voltage generating circuit
10	matrix drive circuit
11	cell
12	pattern electrode
12-1 - 12-3	pattern electrode (electrode 1 - electrode 3)
13-1 - 13-3	pattern electrode (electrode 4 - electrode 6)
21	chuck
22	scorotron discharger
23	surface potential meter

[Identification of Document] DRAWINGS

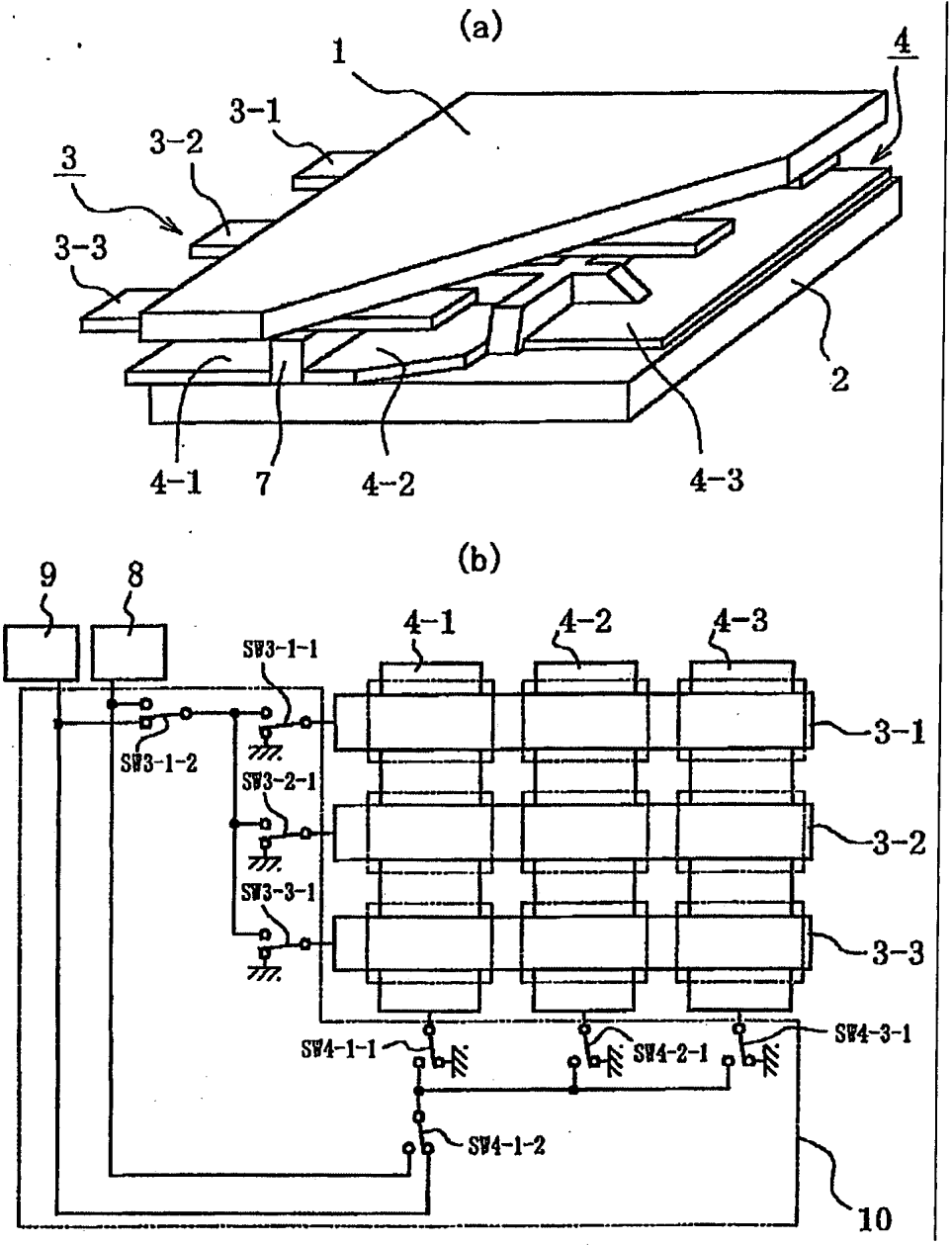
【図１】

[FIG. 1]



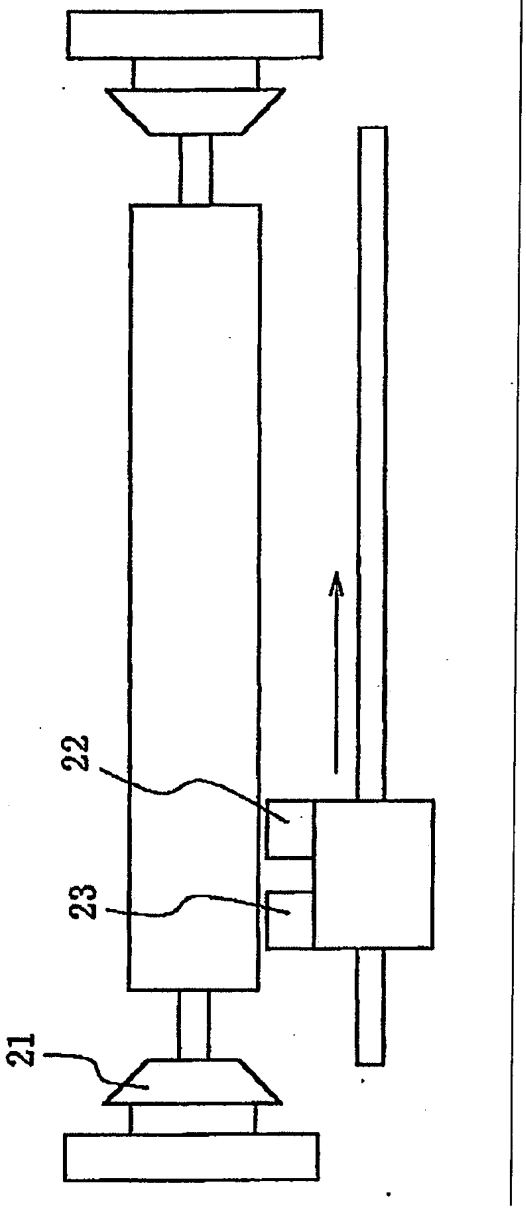
【図２】

[FIG. 2]


(a)
1
4
3-1
3-2
3
3-3
2
4-1
7
4-2
4-3
(b)
9
8
4-1
4-2
4-3
SW3-1-1
SW3-1-2
SW3-2-1
SW3-3-1
3-1
3-2
3-3
SW4-1-1
SW4-2-1
SW4-3-1
SW4-1-2
10

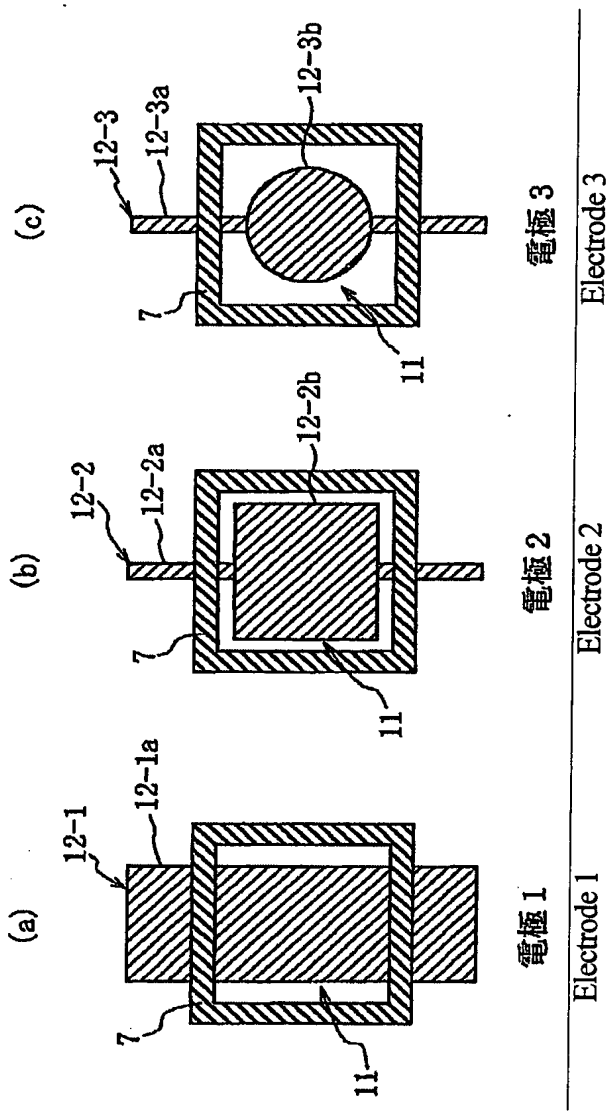
【図３】

[FIG. 3]



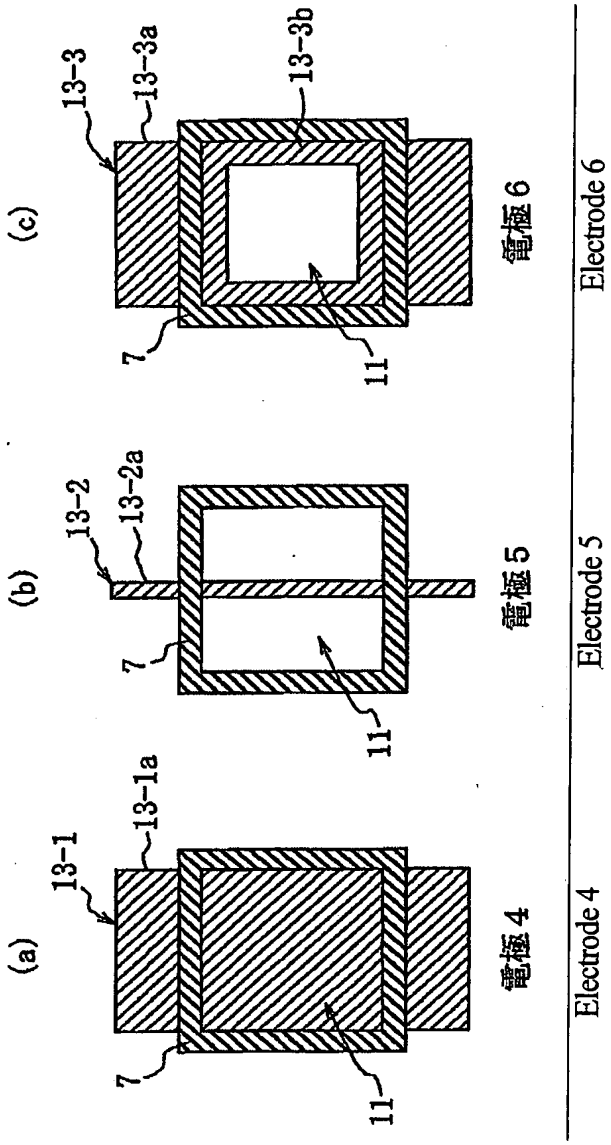
【図４】

[FIG. 4]


(a)
12-1
12-1a
7
11
電極 1
Electrode 1
(b)
12-2
12-2a
12-2b
7
11
電極 2
Electrode 2
(c)
12-3
12-3a
12-3b
7
11
電極 3
Electrode 3

【図５】

[FIG. 5]


(a)
13-1
13-1a
7
11
電極４
Electrode 4
(b)
13-2
13-2a
7
11
電極５
Electrode 5
(c)
13-3
13-3a
13-3b
7
11
電極６
Electrode 6

[Identification of Document] ABSTRACT

[Abstract]

[Task] It is to provide the image display device having rapid response rate due to a dry type display, simple construction, inexpensive cost and excellent stability, and enabling to display image having an excellent uniformity.

[Solving Means] In an image display device which includes an image display panel, in which two kinds of particles having different colors and different charge characteristics, that is, a positively chargeable particle 5 having white color and a negatively chargeable particle 6 having black color are sealed in a plurality of cells 11 formed by partition walls between a transparent substrate 1 and an opposed substrate 2, and, in which the particles 5 and 6, to which an electrostatic field is applied from a display electrode 3 provided on the transparent substrate 1 and an opposed electrode provided on the opposed substrate 2, are made to move so as to display an image, as the electrodes 3 and 4 provided on two substrates, use is made of a pattern electrode 12-1 - 12-3 patternized in such a manner that a coating area of the electrode satisfies a predetermined condition with respect to a projected area of respective cells 11.

[Selected Figure] Fig. 4